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Matching supply and demand: A typology of climate services

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ABSTRACT

Climate services bear the promise of becoming a new, remunerative market of knowledge-intensive services. Although several climate services have been developed, there has been little reflection on the kinds of services such a new market could encompass, and on the ways in which formats can be created that match supply and demand. Using a research approach based on Constructive Technology Assessment (CTA), this article presents a typology of climate services, with types called 'Maps & Apps', 'Expert Analysis', 'Climate-inclusive Consulting', and 'Sharing Practices'. This typology, which is conceptually elaborated and empirically illustrated, structures the variety in current and potential climate services. It provides a framework for the development of climate services and helps users and producers to explore and articulate alternatives for matching supply and demand. On the basis of our analysis we also point towards a more differentiated and broader conceptualization of climate services.

Practical implications

Climate services potentially form a societally relevant and profitable market for consultancies and meteorological research institutes. To develop this new market, a shift is required in which the attention for gathering observational data and creating accurate models is complemented with attention for the demand side and a focus on users. In this shift, different kinds of climate services can be considered.

Using a method based on Constructive Technology Assessment (CTA), we present and illustrate a framework articulating ideal-types of climate services. This framework has proved useful in the interaction with diverse stakeholders to classify current and potential climate services, to articulate preferences and to identify challenges for users and service providers. Underlying this framework are two dimensions, related to how services are offered to the market. One dimension differentiates between services that are tailored to the needs and wishes of specific customers, and services that are developed as a general offering to a large group of customers. The second dimension differentiates between services that are brought to the market as 'climate services' as such, and climate services that are an integral part of broader packages. Table 1 presents an overview of the main characteristics of the different service types and identified conditions for implementation.

This framework can be used by actual and potential providers of climate services to reflect upon the general outline of their services. The framework is also meant for potential users of climate services, to articulate the kind of services they need, given their specific situation, and to explore with service suppliers how to fulfil these needs. *Maps & Apps* are made publicly available, and can help knowledgeable users with their decisions regarding designs, investments, risk management and policy measures, but when it comes to complex or unique climatological conditions and decision-making situations, this kind of service has limitations to its added value for users. *Expert Analysis* is better able to deal with climatological complexities and geographical uniqueness, but may disconnect with other risks and issues in complicated decision-making situations. In such situations, *Climate-Inclusive Consulting* has the most potential to add value for users, especially when these are less knowledgeable of climate issues. Customized services come at a higher price, though. It must be emphasized that different users may have different perceptions of the complexity of their geographical conditions and decision-making situations, depending, among others, on their knowledge

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and previous experience with climate services and related decision-making. In *Sharing Practices* experienced and committed users become providers of climate services themselves, which adds value for users who want to receive advice, or reach out and receive feedback from others who operate in comparable situations.

This framework also assists policy-makers to reflect upon the kind of services they want to stimulate through funding, procurement, or other measures. Public bodies may want to stimulate Maps & Apps and Sharing Practices as common goods for broad use in society, invest in increasing detail and suitability for complex situations, and in raising commitment from a broader group of users. Expert Analysis and Climate-inclusive Consulting need public support in the form of data infrastructure, education and expertise development. Supporting these services helps to professionalize climate services and to stimulate their uptake in complex and institutionalized settings.

1. Introduction

Service innovation can be a powerful means to create new markets (Berry et al., 2006; De Vries, 2006; Snyder et al., 2016). In recent years, a promising new branch of knowledge-intensive services has started to develop, aimed at the anticipation and mitigation of the effects of climate change on society. These 'climate services' are specified by the European Union's Directorate-General for Research and Innovation (2015) as "the transformation of climate-related data—together with other relevant information—into customised products such as projections, forecasts, information, trends, economic analysis, assessments, counselling on best practices, development and evaluation of solutions and any other service in relation to climate that may be of use for the society at large". These services are not only considered as relevant means to deal with climate challenges, but also as a new service market in which Europe could take the lead (Street, 2016). Over the last decade, both discourse and practices related to climate services have changed. Next to discussions on what climate services are and why they are important in general, attention is rising for how these services can be organized, developed and delivered, and how they can add value to specific decision-making processes (Harjanne, 2017). Relatedly, the attention for the supply-side of climate services, in particular gathering observational data and creating accurate models, is complemented with attention for the demand side and collaboration with users (Cochran and Teasdale, 2011; Hewit et al., 2017; Castán Broto and Bulkeley, 2013), both regarding impact (Reinecke, 2015) and process (Cortekar et al., 2016; Schenk et al., 2016). Capela Lourenço et al. (2016) even plea for a further shift, from being 'science-based and user-informed', to being 'user-based and science-informed'. The engagement of users is widely supported in literature, although co-creation processes are still relatively rare in practice (Vaughan et al., 2018).

When searching for new formats to match demand and supply of climate services, there are at least three basic questions to consider (cf. Al-Debei and Avison, 2010; Ghezzi et al., 2015): Which added value has a service for users, how can this value be created by suppliers, and how will the service be paid for? In literature, several answers to these questions have been proposed (Vaughan and Dessai, 2014), but these mainly remain tentative by lack of empirical evidence of the effectiveness of services (cf. Alexander et al., 2016; Hamaker-Taylor et al., 2017). There is still great need for research and reflection on which services are possible, or preferred in this new field. Development of climate services is challenging. Currently, there are many uncertainties, ambiguities and complexities. Regarding demand, it is often not clear for potential users what a climate service is and which added value it may have, and in which phases of complex decision-making processes it can be used. It is a fuzzy and contested concept (Harjanne, 2017; Vaughan et al., 2018), which does not necessarily resonate in the vocabulary of decision makers. What is at stake for them may not be 'climate' as such, but some task related to administration, risk-management, or design, to which 'climate' is but one aspect. Furthermore, the provision of climate services depends on available observational data, models and upstream data services, which are part of a complex and still developing infrastructure including a myriad of institutes and consortia, which adds to the uncertainty (Hamaker-Taylor et al., 2017). Therefore, it may be unclear for suppliers whether it is possible to actually deliver credible and salient services envisioned by potential end-users (Reinecke, 2015). Moreover, climate services have both been presented as commercial services and as public goods, resulting in ambiguities about what kind of service market this is.

To advance the development of viable climate services, there is a need for frameworks that help to provide a structure for matching supply and demand, given the complexities and ambiguities of this emerging new service field. The purpose of this article is to contribute to fulfilling this need. Using a method based upon Constructive Technology Assessment (CTA), we will present and elaborate a framework presenting different types of climate services, and discuss issues related to demand, supply, and funding. This framework has been used in interactions with users, producers, and other stakeholders to explore these types, which has resulted in empirical illustrations, and the identification preferences and challenges related to the development. This article does not aim to evaluate climate services, nor to propose specific services, or to provide a comprehensive overview of problems and opportunities for service development in specific fields. These are steps for further research, which are partly taken up in other articles in this special issue. This article presents a framework for rethinking service formats and for approaching user groups and individual users in different sectors in order to create a versatile basis for exploration and mapping of supply and demand of climate services.

We will first introduce CTA and elaborate how this approach was used in this study. This requires clarification, as in CTA the way in which frameworks are constructed and data is collected differs from more regular approaches of social science research such as surveys and case studies. Second, we will present the typology of climate services and elaborate its general features. Subsequently, we will describe how this typology was used in explorative workshops and interviews to engage with prospective users and other stakeholders. Based on these engagements, we will empirically illustrate the different types and articulate preferences, problematic issues and conditions for their implementation. After that, we will discuss structures related to demand, supply, and revenue streams. The article concludes with the contributions to literature, limitations and suggestions for further research.

2. Constructive Technology Assessment for climate services

Constructive Technology Assessment has its origins in the late 1980s and 1990s, when it was developed as an instrument for the prospective and reflexive shaping of emerging technologies (Rip et al., 1995). Over the years, CTA has been theoretically and methodologically developed by scholars in the field of Science and Technology Studies, in particular by Arie Rip and his colleagues (see, e.g., Rip and Robinson, 2013; Rip, 2018), and applied in different countries and on different technologies, including electric vehicles (Hoogma, 2000) and nanotechnology (Parandian, 2012). The bottom line is to get relevant actors together at an early stage of technology development, to insert scenarios based on a thorough analysis of the technology and its context, in order to enable anticipatory learning (Rip et al., 1995; Rip and Te Kulve, 2008). Central to CTA are stakeholder interactions, normally in workshops that are designed as 'micro-cosmoses', condensed representations of the stakeholder field. In these workshops, 'enactors' and 'selectors' (Garud and Ahlstrom, 1997) are brought together. Enactors are the promoters and developers of a new technology, who regard the development of the technology as progress, often identify with the product, and treat opposition as barriers to overcome (Rip and Te, Kulve, 2008). Selectors, such as consumers and regulatory agencies, have a broader perspective,

Table 1
Alternative climate services.

	Generic	Customised
Focused	**Maps & Apps** ***Characteristics*** ● Easily accessible and cheaply available climate data and projections enable more robust and better justified decision-making regarding investment risks and the anticipation of climate change in less complex situations ● Public institutes use well-known digital formats to bring unified climate data and projections directly to users ● Primarily public funding ***Conditions*** ● Knowledgeability of users ● Existence of a unified data infrastructure	**Expert Analysis** ***Characteristics*** ● Precise and tailored climate data and projections enable more robust and better justified decision-making regarding investment risks and the anticipation of climate change in complex climatological situations ● Commercial climate experts analyse data and models to produce contextualized projections and advice ● Revenues from private and public clients, with public funding to support the data and knowledge infrastructure ***Conditions*** ● Recognition of climate issues by users ● Professionalization of climate experts
Integrated	**Sharing Practices** ***Characteristics*** ● Integral and cheaply available advice enables more robust and better justified decision-making regarding the anticipation and mitigation of climate change in comparable situations ● Peers share best practices, including experiences with climate projections ● Primarily public funding and non-monetary rewards ***Conditions*** ● Knowledgeability of 'prosumers' ● Creation of effective exchange platforms ● Establishment and maintenance of constructive cooperative/competitive dynamics	**Climate-inclusive Consulting** ***Characteristics*** ● Integral and tailored advice enables more robust and better justified decision-making regarding investment risks and the anticipation and mitigation of climate change in complex decision-making situations ● Engineering, management, or policy consultants include climate data and projections in client-focused, well-established services ● Revenues from private and public clients, with public funding to support the data and knowledge infrastructure ***Conditions*** ● Creation of synergies between climate services and non-climate services ● Sufficient awareness and climate expertise among consultancies

and compare various options. By facilitating constructive dialogues between enactors with potential users, regulators, and stakeholders with different perspectives, CTA reduces the costs of 'trial & error' learning for an emerging technology. To enable these dialogues scenarios are constructed that relate technology development to its embedding in society and the encountered tensions. These scenarios are considered 'endogenous futures', projected from an analysis of the current issues and state-of-affairs of the field (cf. Van Oost et al., 2016). Thus, they are not speculative visions of far-away futures, but plausible sketches of nearby alternatives, taking up perspectives of relevant actors, systemic factors, and existing tensions. They are phrased in a realistic yet thought-provoking manner, to be used as objects of discussion on alternative options.

In CTA, technologies are not just seen as artefacts, but as configurations that work as part of a broader socio-technical system (Rip and Te Kulve, 2008). The same perspective can be applied to services (Vargo et al., 2017). Services are not simply transactions between providers and consumers, but multi-level interactive systems that need to be internally and externally aligned to create value for users and revenues for a variety of actors (Pincetl et al., 2016; Scrieciu et al., 2013; Marechal and Lazaric, 2011). Developing a new branch of services such as climate services entails exploration and alignment of expectations, plans and activities on multiple levels, in a variety of public and private organizations (cf. Geels et al., 2017). It involves aligning the socio-technical elements of what Edwards (2010) calls the vast machine of climate knowledge infrastructure, the interlocking systems around the collection and assembly of observations and models of climatological systems (Hamaker-Taylor et al., 2017), which are crucial in knowledge-extensive service provision and utilisation (Hipp and Grupp, 2005). Developing such a complex system of demand and supply requires responsive and reflexive approaches to communication between providers and users during the whole process, with ample resources for dialogue (cf. Brasseur and Gallardo, 2016; Cortekar et al., 2016; Buontempo et al., 2018), as well as local capacity building, inter-organisational collaboration, and citizen involvement (Hoppe et al., 2016). It should go beyond the direct users and producers and involve the wider 'innovation ecosystem' (Adner and Kapoor, 2010). As such, the development of emerging services resembles the development of emerging technologies, requiring the same kind of alignment and being subject to the same kind of uncertainties and ambiguities regarding the preferred direction, the added value, and the alternative ways of supply. A CTA approach can therefore help to enable anticipatory learning among providers, users and other stakeholders of climate services.

3. Types of climate services

In this study, four 'scenarios' have been developed in the form of types of climate services, named Maps & Apps, Expert Analysis, Climate-inclusive Consulting, and Sharing Practices. In CTA exercises, scenarios are plausible and thought-provoking narratives of alternative nearby futures. In our study, we did not develop scenarios in a narrative form, but constructed a set of ideal-types of services, as plausible sketches of alternative kinds of climate services. An advantage of a typology over a set of narratives is that it serves better as a basis for identifying current services, imagining future ways to match demand and supply, and stating preferences. Besides, a typology is easier to use under time constraints and in smaller settings, such as interviews and small focus groups. Underlying our typology are two dimensions related to how the service is offered to the market, the first related to 'customization', the second to 'integration'. Both dimensions are implied in the European research and innovation roadmap for climate services (DG for Research and Innovation, 2015) to characterize services for different kinds of customers and the complexity of decision-making situations (next to other characteristics, which are more content related). The customisation dimension differentiates between services that are tailored to the needs and wishes of specific customers, and services that are developed as a blanket offering to a larger group of customers (cf. Lovelock, 1983; Heusinkveld and Visscher, 2012). The integration dimension differentiates between services that are brought to the market specifically as 'climate services' (distinguished from other services), and climate services that are not offered to clients as such, but as integral parts of broader packages, including a range of non-climate services (Räsanen et al., 2017), aimed at policy making, management, or decision-making processes. These dimensions are particularly useful for our purposes because they do not only distinguish between different

Table 2
A Typology of Climate Services.

	Generic	Customised
Focused	**Maps & Apps** ● General climate services ● For all users ● Made freely or cheaply available	**Expert Analysis** ● Mono- or multidisciplinary climate services ● Tailored to specific decision-making situations ● Offered commercially
Integrated	**Sharing Practices** ● Mutual climate- and climate policy services ● Among knowledgeable peers ● Made freely or cheaply available	**Climate-inclusive Consulting** ● Interdisciplinary management, engineering, or policy services including climate data ● Tailored to specific decision-making situations ● Offered commercially

kinds of customer needs, but also between ways of supplying services. Table 2 gives an overview.

This typology presents ideal-types (Weber, 1904/1949) of climate services – partly based on currently available services, and partly on promises, expectations and preferences. Concrete climate services are seen as instantiations of these types, which get meaning in specific contexts and practices (Heusinkveld and Visscher, 2012), and which may contain elements of other types as well. The types are separated analytically to articulate generic ways of matching supply and demand, and to identify preferences, problems, and possibilities of different stakeholders. Besides characteristics of 'users' and 'service providers', these types also include more context-sensitive dimensions related to technological features of climate service provision, and requirements for value creation. These types are not normative, nor do they provide descriptions of the current state-of-affairs of climate services, but they provide heuristics (Abbott, 2004) for sorting out the ways in which de facto climate services could develop, and for starting a conversation on the co-construction of new services among stakeholders.

In the *Maps & Apps* ideal-type, climate data and projections are provided on a national, regional, or local level to large groups of civil servants, policy-makers, managers, entrepreneurs and citizens, which they can consider when making decisions on infrastructure, investment portfolios, policy measures, etc. Users have quick and inexpensive access to relevant data and projections, which make individual and collective decision-making processes more robust and objective. The availability of reliable information may reduce conflict and enable reaching consensus. Central in the provision of Maps & Apps are meteorological and research institutes, as well as intermediary bodies that bring data and user foci together, creating easier to use and more practically relevant visualisations (e.g., GERICS Climate Signal Maps, NASA's Climate Time Machine). Because revenue streams from users are limited – due to free availability of the service, or restrictions for these institutes to operate commercially – public funding from national and international bodies is the major source of funding. This implies also political influence on the direction of developments. In order to deliver credible and salient services, Maps & Apps are ideally based in a unified, open source (observational) data infrastructure and in collectively developed reliable climate models. In this type, users are supposed to be capable of interpreting Maps & Apps and relating them to their specific decision situations. Effective user-interfaces (e.g., Google's 'Climate Engine', 'Google Earth Outreach') which are applicable in a variety of decision-making contexts are crucial to ensure relevance, usability, legitimacy and credibility of these services. Interfaces are likely to be developed in public-private partnerships, collaborating with users to improve their satisfaction based on intensive feedback. Commercial application designers may also take the lead in creating user interfaces and making them available to a large audience. When taking into account the broader service system, several conditions for the realization of this type of services need consideration. These include the unification of the data-infrastructure, the availability of high-quality user-interfaces (in relation to the knowledgeability of the intended users), the accuracy, legitimacy and credibility of data and projections, and the alignment of interests and revenue streams in public-private cooperation.

In the *Expert Analysis* type, climate experts have a pivotal role. Although the initiative is with users, who should recognize and acknowledge the relevance of climate data for their decisions, and show willingness to pay, they do not need to assess and interpret the data and projections themselves, as was the case with Maps & Apps. Climate services are provided by specialized, commercial consultancy firms and market-oriented branches of meteorological and research institutes, which contextually interpret climate models to deliver tailored analyses regarding projections, climate policy, and mitigation arrangements. Users demand and pay for these services, individually or as part of a collective, and reap the benefits by better risk assessments, design decisions, policy measures, etc., specific for their local situation and the decision at hand. As these services are offered commercially, the market is assumed to select viable services. Meteorological and research institutes also deliver meta-services to specialized consultancies in the form of observational data and climate projections. Climate experts, which are educated at dedicated academic and professional programmes, are able to deal with the complex data infrastructure and are able to match data and projections with a variety of user contexts. Therefore, less unification of data and homogenization of demand is required. Governments play a role as clients of these climate services, but also as supporters and legitimizers of the professionalization and development of meta-services. Conditions for the development of this service type are clear demand articulation by users, expertise development, and professionalization of climate service providers vis-à-vis other, often more established fields of expertise.

In *Climate-inclusive Consulting*, commercial, interdisciplinary consultancies – such as engineering, urban planning, finance services, policy or management consultancies – create and deliver climate services by integrally taking climate data and projections into account when advising decision makers on a broad range of subjects, such as infrastructure, investments or corporate strategy. Users may take the initiative and ask for the integration of climate data, but they do not have to beforehand recognize and name specific climate issues, or to interpret climate projections and analyses for their decision-making. Consultants do that for them and in collaboration with them. Value for users is created by more robust designs and more prudent and effective decisions, customized to the customer's decision-making situation, and made possible by consultancies with a strong user orientation. As in the Expert Analysis scenario, users will provide the main revenue stream for these services; the main difference is that it is the consultant rather than the user who specifies climate issues and integrates these in broader decision-making and implementation processes. Detailed climate analyses may be subcontracted by specialized agencies or departments of the consultancy firm itself, or based on a contextualized interpretation of publicly available maps and apps. Meteorological institutes provide meta-services or expert input in terms of measurements and projections. In this ideal-type of services, an at least moderately integrated data infrastructure is required, supported by government funding. As such, these commercial services are built on publicly provided meta-services and infrastructures. Conditions for the development of this type are the uptake of climate services by larger consultancy and engineering firms, both internally and in the relations with their clients, and the development of sufficient expertise within these organizations and their networks.

In the *Sharing Practices* type, users of climate services are basically also the producers of climate services. The identification of best practices and the sharing of experiences among knowledgeable peers – for instance local governments within a certain region, or companies within a certain branch – is central to the provision of these services. The exchange of services within these communities is facilitated by databases, platforms and events, which are partly sponsored by public bodies, and partly offered by commercial platform providers. These services relate to actual decisions and policy measures, which are integrated in more encompassing contexts of use. They originate from specific situations, but are made more generic in the ongoing exchange processes and by connecting them to other types of climate services. Relevant climate data and projections are provided as meta-services, by meteorological and research institutes, or their maps and apps, based on open data. Expert consultancies may play a role as knowledge brokers, or as trainers of participants of networks, or they can measure effectiveness, or provide specific expertise when this is needed to tailor shared practices to a different local context. Sharing maps, apps and knowledge may also make new tools visible and suggest them for trial, such as UK Met office's 'SciTools', developed in collaboration with a broader community of partners in earth sciences, with open-source data for analysis and visualisation. Condition for the development of this type is the willingness of users to develop sufficient knowledge on climate change analysis, adaptation and mitigation, and to share and generalize this knowledge with others, also in competitive situations or situations with scarce resources. Training can support the necessary learning of users.

4. Method

CTA exercises consist of two stages (Rip and Robinson, 2013). In a first stage, literature study, document analysis, and explorative interviews with experts are used to get acquainted with the field and to identify issues, tensions, and different actor positions. Based on these insights, the scenarios are constructed. The second stage focuses on interactive 'bridging events', either workshops or other interactive sessions, for which stakeholders are selected to discuss the scenarios, to articulate their preferences, and to reflect on their and others' positions in the emerging field. Participants ideally include insiders and outsiders, enactors and selectors, 'usual suspects' and people providing unusual angles. A CTA researcher facilitates (and influences) the learning process by conducting the exploratory research, drafting the scenarios, and moderating the discussion (Rip and Robinson, 2013).

There is a variety of ways in which CTA exercises can be prepared and executed, ranging from dedicated workshops based on meticulously researched scenarios (e.g., Parandian, 2012), or series of workshops within a bigger project (Aukes et al., 2019), to shorter and lighter versions, framed by Schulze Greiving-Stimberg et al. (2016) as 'CTA-Lite'. In the Horizon 2020 project 'European Market for Climate Services' (EU-MACS), on which this paper is based, we deployed varieties of 'CTA-Lite'. This was done for practical and content-related reasons. With lighter versions, it became possible to combine stakeholder interactions organizationally with other interactive events in the project, such as living labs, business development, and stakeholder interviews, which eased the access to stakeholders, helped to tailor the activity to the specific field, and created the opportunity for our activities to inspire and be inspired by other climate service related activities.

The preparatory work consisted of studying policy documents – in particular the research and innovation roadmap for climate services (DG for Research and Innovation, 2015) – and articles reporting on concrete climate services (e.g., Schenk et al., 2016), as well as interviews with members of or connected to the EU-MACS consortium. On the basis of this study, the typology of climate services was created through abductive reasoning (cf. Ketokivi and Mantere, 2010), which involves a 'creative leap', based on gathered insights, to a framework that sensibly structures the variety of (potential) services. The typology was subsequently used to probe service types with stakeholders, as well as to collect concrete examples of the presented types of services. The interactive events took place in the three focal sectors of EU-MACS, viz. tourism, urban planning and finance services. Workshops were designed on tourism in Austria and on urban planning in Finland (see Stegmaier and Visscher, 2017). In the tourism workshop, six consortium members and ten external stakeholders participated (representatives from tourism service providers, tourism associations, public administration, and climate service providers). In the urban planning workshop three consortium members and seven external stakeholders from academia and the municipality participated. For the finance sector, a slightly different format was used. Due to practical and competitive reasons, a workshop with all relevant participants was not possible. Therefore, the typology was inserted into individual and small group interviews with stakeholders. Seven interviews were conducted involving sixteen individuals from twelve different organizations, including investment consultants, asset managers, and staff from a development finance institution (DFI) and a rating agency. Sectoral studies and experts were used to select these stakeholders.

In the CTA workshop in Finland, which was held in the local language and took about 90 min, the following protocol was followed. First the goal of the workshop and the typology were introduced through a powerpoint presentation. This created a shared understanding of the types and their main characteristics (as described in Section 3). Also, conditions for the different types, related to the broader service system (such as the required data- and knowledge-infrastructure), were mentioned, to entice the participant to take a broader view of service development. After that, the stakeholders sat together in subgroups with a moderator, who asked the participants to come up with an actual or possible example of each of the service types. This led to further understanding and concretization of the typology. Subsequently, the participants individually articulated their preferences and ideas about implementation by dividing six points regarding desirability and six points regarding doability among the four types. A round was made in which the stakeholders –both enactors and selectors – gave an argumentation for their scores. This was the input for a group discussion on the desirability and doability of the service types, first the most desirable, then the least desirable, and then the two in-between. This was followed by a dialogue, taking an enactors' perspective, on what needed to be done to realize preferred climate services, including questions like 'which stakeholders should be involved', 'how should collaborations be shaped', and 'which barriers are expected'. The workshop was concluded with a plenary reflection on learning experiences. The tourism workshop in Austria followed the same protocol and took 150 min. For the study in finance, the workshop protocol was translated into an interview protocol, which roughly included the same steps: Introduction of the typology, describing concrete examples, articulating desirability and doability, and discussing the process of further service development. As there was no or little group interaction, interviewees were given the opportunity react to examples and preferences of earlier interviewees.

During workshops and interviews, notes were taken regarding examples, preferences and challenges for the service development. To follow up on the examples, an internet and literature search was carried out to find more detailed information. To analyse the data, the typology was used as the structuring framework. The examples were classified, as were the notes regarding preferences and challenges. The results of these can be found in the next two sections.

5. Climate services in tourism, urban planning and finance

In this section, examples of actual or possible climate services will be provided, which were brought up in the workshops and interviews.

These specific service examples are meant to clarify the different types and to show which user demand they can fulfil, by whom they are created, and whether they are paid for by public, private, or combined funding. Because of the background of workshop participants, examples in tourism mostly come from Alpine winter tourism, while examples in urban planning relate to experiences in Finland. The examples from finance are more diverse. As is common with typologies, not all concrete services fit with only one type. We therefore also portray a few services that combine features of different types.

5.1. Matching supply and demand in climate services for tourism

Maps & Apps provide generic information on climate change impacts on tourism (e.g., changes in snow conditions, tourism demand). One example is the IMPACT2C Atlas,[1] an outcome of the EU FP7 project IMPACT2C, showing the impacts of +2 °C global warming on different sectors, including the tourism sector. CLIMAMAP, a project funded by the Austrian climate and energy fund, provides fact sheets of climate change impacts for each Austrian province, using several climate indices (tourism relevant indices include, e.g., number of hot days, number of days with ideal weather for swimming). Climate indices data and fact sheets are downloadable from the Austrian CCCA data portal.[2,3]

The information available on these online platforms is rather general in their nature, usually not taking into account specificities of the respective microclimates, local strategies and adaptive capacities. Expert Analysis and Climate-inclusive Consulting, on the other hand, can take – to a certain degree – this local information into account.

A typical example of *Expert Analysis* is tailored snow simulations, adding value to investment decisions of an individual ski resort. Compared to generic study results, these tailored services can provide higher spatial resolution and take local measurement data and individual snowmaking capacities into account. Information that could be provided include, e.g., the change in average season length, the change in the probability of ski operation during Christmas holidays, the change in the minimum number of operating days in 90% of winter seasons, or the required amount of technical snow to maintain a 100-day season. In addition, snowmaking options under current climatic conditions can be analyzed, including the variability in season length given increased snowmaking capacities (cf. Köberl et al., 2018; Damm et al., this issue).

Based on tailored snow simulations, further economic assessments are possible, e.g., climate-proofing of investment decisions. An example of *Climate-inclusive Consulting* could include the assessment of a ski area's importance for the regional economy, the assessment of the area's risks towards climate change, the analysis of opportunities and challenges associated with the establishment of a bike park in this area, and an economic feasibility study of the different investment options. The analysis would be based on tailored snow simulations (i.e., Expert Analysis), accounting for the ski area's specific snowmaking capacities and extension plans. Using data on current skier days and sales, changes in ski season length can be translated into monetary terms and incorporated into the economic feasibility study of the investment options (cf. Köberl et al., 2018).

In the EU-MACS CTA workshop for tourism in Austria, participants were first not able to come up with examples of *Sharing practices* in the tourism sector related to climate services. However, a ski resort operator mentioned in this workshop a concrete example of sharing practice among ski resort operators in another field: neighboring ski resorts jointly commissioned a market research study, including individual consulting for each ski resort. This could be an example for the use of climate services as well, e.g., joint acquisition of tailored snow simulations for a specific tourism region, and a starting point for sharing experiences on how to deal with decreasing snowfall.

5.2. Matching supply and demand in climate services for finance

In the category of *Maps & Apps*, we found open access portals with information on essential climate variables (temperature, precipitation, sea-level, etc.), as well as free portals or tools, which allow for assessments of impacts to sectors or geographies. The World Bank's Climate Change Knowledge Portal (CCKP)[4] is an example of a web-based tool in the Maps and Apps category. It provides access to global, regional, and country level data on observed records of climate variables. Created by, and for, the World Bank, with support from the Global Facility for Disaster Reduction and Recovery (GFDRR), this service is now also publicly available. It has value for staff within the bank as they are working to gather climate risk information during the development of projects, and it allows staff to populate the Bank's internal risk screening tool. The CCKP provides historical data along with climate change projections based on emissions scenarios from the Intergovernmental Panel on Climate Change (IPCC). According to interviewees, the portal also offers numerous other features including country-based adaptation profiles, sector specific information, and information relating to climate mitigation. The World Bank has also developed climate risk screening tools, developed for internal assessment purposes, targeting sectors where investment is concentrated such as agriculture and health. These tools are constantly evolving at the World Bank, with the recent development of rapid assessment tools based on the original tools now being offered. Other examples are hazard maps, climate change scenario maps, non-sector specific screening tools, the KNMI Climate Explorer, the monthly maps and charts from Copernicus climate change service, and EU Climate Adapt map viewer.

With *Expert Analysis* we can associate commercially offered tools that allow for assessment of climate change risks. These models aim to add value to investment portfolios, aggregating calculated climate risk, associated with extreme events. Thought leadership guidance documents can also be seen as examples of Expert Analysis and are commonly produced. For instance, The Global Investor Coalition on Climate Change developed 'Climate Change Investment Solutions' targeting asset owners. These documents are tailored to different segments of the finance sector, and to some extent tailored to the management level within the organisations. They are typically published open access, though will often be funded by membership-based organisations. The Global Investor Coalition on Climate Change, for example, is made up of various investor groups such as the Investors Group on Climate Change (IGCC) in Australia and the Institutional Investors Group Climate Change (IIGCC) in Europe – whose members typically pay an annual fee to be a part of. Those groups commission consultants to produce guidance reports, and often make them publicly available. In that sense one could say these services are between Sharing Practices and Expert Analysis.

In order to illustrate *Climate-Inclusive Consulting*, we could consider a typical example: A financial institution might be interested in investing in the construction of a new cargo terminal in a port in the Pacific coast of Mexico. Before it embarks in the negotiations with relevant parties, it wishes to examine the risks of flooding that the port is exposed to and how these risks may affect the economic performance of the port in the future. To do this, the bank commissions a detailed study from a consultancy, which will include the climate risks and a strategy on how to reduce these threats.[5] Catastrophe models ("cat models") are another

[1] www.atlas.impact2c.eu/en [4 March 2019].

[2] https://data.ccca.ac.at/en/dataset/climamap-climate-indizes-karten-steiermark-v01 [4 March 2019].

[3] www.ccca.ac.at/wissenstransfer/fact-sheets/ [4 March 2019].

[4] http://sdwebx.worldbank.org/climateportal [4 March 2019].

[5] Cf. www.acclimatise.uk.com/2016/05/11/report-port-of-manzanillo-climate-risk-management [4 March 2019].

example of Climate-Inclusive Consulting. The vast majority of cat models are produced by a handful of commercial model vendors. Otherwise, these are provided by brokerage firms and at times specialist consultants.

DFIs are often involved in the creation of *Sharing Practices* services, which they also use internally. The World Bank, for example, has recently developed a self-paced course on it's Open Learning Campus[6]. A stakeholder from the World Bank explained the added value of the course was to advance understanding, awareness and uptake of climate services. A series of knowledge sharing sites have started to emerge as well, including the Climate Mainstreaming Practices Database,[7] which facilitates knowledge sharing between financial institutions and provides case studies written by supporting institutions, which share how they are integrating climate change in their operations. Sharing practices are also provided in the form of best practice guidance documents. A prime example is the European Bank for Reconstruction and Development's partnership with the Global Centre of Excellence on Climate Adaptation (GCECA), predecessor to the current Global Center on Adaptation (GCA) which sought to engage with members from the finance, corporate and regulatory sectors.[8] Together, members of this group produced a set of guidelines for corporations to use when analysing and disclosing their physical climate risks and opportunities. While the aim of this initiative was to inform and support early efforts of corporates to adopt the TCFD recommendations, an interviewee argued that the guidelines can also be used by asset managers and banks as an engagement tool with their corporate clients.

5.3. Matching supply and demand in climate services for urban planning

A good example of a *Maps & Apps* service is the publicly accessible, interactive flood risk map application for Finland, provided by the Finnish Environment Institute. It serves both citizens and experts, by offering different sophistication levels. Helsinki and the Helsinki Metropolitan Area Environmental Service (HSY) offer a host of public climate information and tools to citizens and experts related to urban planning, building design, own house maintenance, etc.[9] All are based on public funding.

There are several examples *of Expert Analysis* provided by commercial consultancy companies, such as a thorough flood preparedness plan[10], which included detailed information on flooding in current and future climate in Helsinki. The local government also commissioned a holistic weather and climate change risk assessment, which was procured through a tender process. The assessment was customized for the city to support various processes and decisions. Other Expert Analysis examples are the Global Climate Risk Index[11] and Climate-ADAPT.[12]

Climate-inclusive Consulting can integrate weather and climate change scenarios, ranging from flood scenarios to urban precipitation patterns, in consultancy packages for planning urban infrastructure, for instance related to the sewage system or heat islands. A representative of the Helsinki municipality said that the municipality is integrating climate change impacts increasingly in its planning.

The Finnish climate change web-portal ClimateGuide.fi is an example of *Sharing Practices*. It is a publicly funded, open information source used to provide cities and municipalities information on the impacts and solutions to climate change. It is also used as sharing benchmarking examples or best practices. Another example of Sharing Practices is the cooperation of the six largest cities in Finland in the web facility 'Ilmastotyökalut.fi' (Climate Tools).[13]

6. Typology in use: Exploration of preferences and challenges

6.1. Maps & apps

For potential users in the workshops and interviews, climate services in the form of maps and apps appeared the easiest to imagine. In urban planning and insurance, maps are familiar formats, and used regularly. In the tourism sector, there is ample experience with meteorological apps, and although these are concerned with weather rather than with climate, they provide a well-known format in which climate services can be seen to fit. In the tourism workshop, Maps & Apps services were deemed very desirable by potential clients such as ski lift managers, especially when user interfaces would be good, preferably giving access to all relevant information by pressing a single button. A potential downside of the connection with weather apps is that it fosters a 'much for nothing' attitude, with people expecting a free app to deliver an accurate and relevant service. Potential users from tourism already complained about the lack of detail of current weather apps, and feared the same for free climate apps, which could lead to disappointment and cynicism.

Regarding the provision of Maps & Apps, the question was raised in the workshops and interviews who could offer such services. Public institutions like meteorological institutes and publicly funded consortia are logical candidates. Large institutes such as the World Bank can also develop maps & apps in-house. For smaller climate service providers with less financial resources, it may be hard to build and maintain such a service. A division of labour in the value chain could be an option. Umbrella organizations or *meta*-service providers maintain a basic infrastructure and provide general applications, while smaller climate service providers build on these to add specific functions. An interviewee made a comparison with online banking, where *meta*-providers maintain an infrastructure for an entire group of individual banks.

Although Maps & Apps are typically made for a larger group of users, they could also develop into more tailored services, either by a more sophisticated map or app, or by using an app as a tool to communicate a request to a service provider, to gather on the spot data, or to link to a subscription model for expert advice. Users would use the app then to order and receive strategic intelligence for their local situation. These applications would not replace the original Maps & Apps services, but complement them. In the finance sector, there was already some experience with these sophisticated maps and apps (see Section 5.2). However, these more tailored maps were not always freely available, or required more knowledgeable and experienced users.

6.2. Expert analysis

Users who had considerable prior experience with climate services often preferred Expert Analysis services over other types, as they wanted very specific advice and trusted their own ability to implement this in their decision-making. In finance, DFIs are advanced users of climate services, often committed to project level climate risk

[6] https://olc.worldbank.org/content/e-platform-weather-and-climate-services-resilient-development-guide-practitioners-and-policy [4 March 2019].

[7] www.mainstreamingclimate.org/climate-mainstreaming-practices-database [4 March 2019].

[8] The expert working groups in the initiative included participants from Agence Française de Dévelopement, Allianz, APG Asset Management, AON, the Bank of England, Barclays, Blackrock, Bloomberg, BNP Paribas, Citi, Danone, the Dutch National Bank, DWS Deutsche AM, the European Investment Bank, Lightsmith Group, Lloyds, Maersk, Meridiam Infrastructure, Moody's, S&P Global Ratings, Shell, Siemens, Standard Chartered, USS and Zurich Alternative Asset Management.

[9] https://www.hel.fi/helsinki/fi/asuminen-ja-ymparisto/ymparistonsuojelu/ohjelmat/ilmasto/; https://hsy.fi/fi/asukkaalle/hillitse-ilmastonmuutosta/ilmastoinfo-toimii/Sivut/default.aspx; https://www.stadinilmasto.fi/ [29 November 2019].

[10] www.hel.fi/hel2/ksv/julkaisut/yos_2010-1.pdf [4 March 2019].

[11] https://germanwatch.org/en/cri [4 March 2019].

[12] https://climate-adapt.eea.europa.eu [4 March 2019].

[13] https://ilmastotyokalut.fi/ [29 November 2019].

assessment, and regularly demanding external Expert Analysis. In tourism, this kind of service also resonated with a well-known weather service. A ski-lift-operator, for instance, can order tailored weather forecasts for skiing on three levels of altitude. They know that detailed weather prognostics for a complex area are highly personnel intensive and tailor-made by experts and therefore expensive. In urban planning, the same goes for the detailed projections of heat waves in a city. Users at the workshops realized that such an analysis cannot be provided for free and that also detailed, high-resolution Expert Analysis combining short-term weather and mid- or long-term climate expertise will cost. Some actors were already investing in such analyses, focusing on specific questions related to demand forecast, planning of staff and investment in infrastructure. These analyses were identified as being reliable but further refinement was still believed to be necessary.

Workshop participants and interviewees expressed limitations to the provision of Expert Analysis services. The topographical and climatological complexities of certain areas, such as the Austrian mountain region with several interfering climate zones, suggest that not everything that users wish for is feasible yet. According to meteorologists, seasonal forecasts in the Alps, for instance, are extremely difficult, if not impossible for the time being. Big coordinated research efforts would be necessary to make this possible in the future. As the costs of Expert Analysis services are related to the big efforts that are often needed for fine-grained analyses, it may be challenging for service providers to deliver an added value over cheaper Maps & Apps services at a price that users are still willing to pay. In the financial sector, this may be less of an issue, but in tourism, with smaller clients, or in the planning departments of smaller cities, this can be a problem. According to stakeholders at the tourism workshop, regional or national associations could play a role in this by procuring expert advice and then selling this or making it available to their members.

6.3. Climate-inclusive consulting

Workshop participants and interviewees who had no prior experience with climate services often preferred Climate-inclusive Consulting services. Potentially new clients explicitly asked for further and more thorough integration of climate services, for instance with economic, ecological, consumer behaviour, and logistic aspects. The integration of climate services into a broader spectrum of better known knowledge-intensive services would help them to link climate-aspects meaningfully to complex questions on strategic planning, such as the development of the touristic season in a specific area. Some more experienced users also recognized the added value of these integrated services. For instance, in insurance, there is a strong reliance on catastrophe modellers, a climate-inclusive service. These modellers integrate climate data with other data, e.g., on earthquakes or political instability, to allow screening of the insurer's portfolio. In the workshops and interviews it was recognized that climate-inclusive consulting often requires expert analysis to some extent, to safeguard the reliability of the advice. For instance, Austrian meteorological institutions gave integrated strategic advice to federal state bodies, in which Expert Analysis was included, but not offered separately. Also, in commercial banking, there are several incumbent consulting firms serving banks, who are now starting to try and integrate climate-related data and information into their services.

6.4. Sharing practices

Sharing Practices were rarely proposed by in the workshops and interviews as most preferred services, and participants first found it harder to imagine fitting examples. However, at closer inspection, there were quite some instances available. This model is well-known in scientific communities and professional communities of practice, as well as in user networks, and the potential was recognized, for instance for upstream services among climatologists and meteorologists through various international scientific and professional organizations. To deliver these services more downstream, it was mentioned that business associations could play a role. In tourism, for instance, obligatory membership in associations such as the ropeways association supports exchange, and the younger generation of managers has shown willingness to do so.

A challenge is that competitive dynamics among users could limit the exchange. However, cooperation still can make sense in competitive environments, for instance by sharing costs for basic analyses and exchange of general best practices, while buying more specific intelligence individually and keeping the details of best practices for the own company and its direct partners. Sharing Practices services then remain limited. The sharing also depends on whether 'climate' is considered an important issue. If not, then people would hardly find it worth the effort, or would not be facilitated by their employer in terms of time and money to share experiences and information. To make the sharing of practices work and communities of practice arise, a need was articulated for open source data, for easily accessible fora and platforms to find suitable exchange partners, and for intermediaries who can serve as knowledge brokers, either between peers, or between users and experts.

7. Discussion

The presented climate service typology contains empirically informed heuristics for the development of climate services. They have been used in our study to stimulate dialogues between enactors and selectors of climate services. The results allow for closer inspection of structures of demand and supply.

At a first glance, the needs climate services can fulfil seem quite alike: better anticipation of climate change in investment decisions, more effective mitigation measures, and better justified policies. In more detail, the needs vary over different sectors, and over geographical and decision-making situations of different complexities and uniqueness, as has been described in the previous sections. From the perspective of an individual user, it could be argued that the usability and relevance for decision making increases when they pay more for the services, which becomes clear when comparing Maps & Apps with the tailored types. Maps & Apps are inexpensive and aim for a large audience, but are often not detailed enough and difficult for laymen to interpret, which limits the added value in more complex situations. Expert Analysis can deal with more climatological complexity and Climate-Inclusive Consulting can cope with more multi-faceted decision-making situations, but they are also more expensive. This relation between costs and added value appears not linear, though, and something to discuss among specific users and providers. In case of more typical local conditions, well-known decision-making situations, or more knowledgeable users, less expensive services may also be relevant and usable. There is also a cumulative effect. When a larger number of localities gets mapped, more sectors get covered, experience with climate-related decisions rises, and the knowledgeability of users grows, less expensive climate services may create added value for a larger group of users, in particular though Maps & Apps and Sharing Practices.

The ways in which services are supplied vary over the four types, with different trajectories and divisions of labour over the value chain. The delivery is most direct when purveyors develop maps and apps that can be used directly by decision-makers. In Expert Analysis, these maps may serve as one of the inputs to create tailored advice, which advice – in Climate-inclusive Consulting – may again be integrated in more encompassing service offers. In the sharing of practices, experiences with implemented (external) advice are fed back into the service market by the users. In this way, climate services encapsulate other climate services and travel different routes through value chains before they reach the end users. This also implies that climate services providers build relations with other purveyors, both in the public and private domain. Public or semi-public actors appear often in the lead in Maps & Apps and Sharing Practices, while Expert Analysis and Climate-inclusive Consulting seem mostly led by private parties, which suggests that public-private collaborations are required to make the whole spectrum of climate services possible. The supply of specific services will depend on the strategies and organizational resources of individual purveyors to create, or rather co-create, relevant, usable, legitimate and credible new services, but – as we argued in Section 2 – also on systemic conditions, which are beyond the control of individual organizations. These relate to, among other things, the available infrastructure of data and tools, the professionalization of the field, the ability to create synergies between disciplines and practices, and the 'coopetitive' dynamics (Bengtsson and Kock, 2000) among users and service providers.

For all four types of services, public and private revenue streams play a role. In the Maps & Apps examples we studies, public funding of the development and operation of the services was dominant. There seem to be relatively little opportunities to get revenues from users, unless climate services are connected to other digital services or business intelligence, more tailored to a specific industry, or offered as a 'freemium' providing free maps but asking money for more detailed analyses or advanced services. In Expert Analysis and Climate-inclusive Consulting, the revenue streams from clients prevail. Users are expected to pay for tailored reports and/or will be charged consulting fees. In Climate-inclusive Consulting this can take the form of a premium or additional hours charged. Public bodies are important prospective clients in sectors like tourism and urban planning. In Sharing Practices, revenue streams from users are likely to be marginal, e.g., subscription and conference fees. As with other open-source communities, these climate services are driven by 'prosumers' spending their time on it without requesting monetary rewards. The reward is related to their intrinsic motivation, status in the field, and the knowledge and services they get in return (cf. von Hippel and von Krogh, 2003).

8. Conclusion

In this article we have argued that in order to develop new services in the emerging knowledge-intensive climate service market, it is useful to create a general structure within which demand and supply can be explored. In particular, we developed a typology with four types of climate services, which have been used in 'CTA-lite' exercises in three different sectors to show inspiring examples of climate services and to articulate user preferences and challenges with supply and demand. It has become clear that the types work to foster productive discussions among diverse stakeholders. The types help, on the one hand, to become more precise about specific forms or combinations of climate services, and, on the other hand, to figure out what is needed to make these kinds of services work in practice. Together, this provides a general framework to explore the contours of alternative climate services, for public and private organizations aiming to offer climate services, but also for potential users and clients looking for services that add value in their specific climatological and decision-making contexts, and fit with their level of experience.

The framework forms a typology, not a taxonomy. It is not claimed that all climate services can be univocally categorized in one of the categories, nor that they should. On the contrary, providers of knowledge-intensive services are often bricoleurs, who blend, tweak and combine different kinds of services to satisfy the needs of their specific customers (Visscher et al 2018). Combining is a creative and contextual process. For instance, climate inclusive consultancy may include a bigger portion of expert advice when novel problems or areas need to be tackled. Also, users can search for combinations. Those who cannot afford tailored advice may find it convenient to use freely available applications or maps, while learning via a user forum how to make the most out of them. In fora, experts may want to share knowledge and insights or correct what they might see as misconceptions on the part of the other participants. From a more sequential point of view, sharing climate problems within a community of users may lead to questions or recommendations, which experts can take on, and expert analyses may lead to requests for more integrated consultancy including non-climatological dimensions (cf. Räsanen et al., 2017). In another direction, Climate-inclusive Consulting may routinize and commodify into more focused, standardized or simplified methods, or even apps that decision-makers can use to deal with partial needs of climate intelligence. All four types of climate services, and their combinations, are required to fulfil the broad range of user needs over a longer period of time.

This study contributes to the literature on climate services by presenting and elaborating a typology and a method that help to structure and critically assess the possibilities for developing services in this emerging field. As such, it provides a general navigation tool for journeys to match supply and demand of climate services, which is currently one of the great challenges in both practice and theory (Reinecke, 2015; Capela Lourenço et al., 2016).

The study also contributes to the conceptualization of climate services. The definition of the Directorate-General for Research and Innovation (2015) pictures climate services as the transformation of climate-related data – together with other relevant information – into customised products and any other service in relation to climate that may be of use for the society at large. We have shown that different types of services put emphasis on some elements of this definition, but not on all elements at the same time: Maps & Apps focus on 'use for society at large', Expert Analysis on 'customised products', and Climate-inclusive Consulting on the combination 'with other relevant information'. Climate services that try to combine all these characteristics might end up being confusing and non-viable. Besides, the definition starts from the transformation of climate-related data, while in Climate-inclusive Consulting and in Sharing Practices, user questions, practices and experiences are the starting point for service delivery, and climate-data may become an integral part of that on some aggregation level. The definition also separates production and use of services, while in Sharing Practices, the distinction between user and producer has largely disappeared, and also for other types, co-creative processes of users and producers are considered relevant. Together, these considerations ask for a differentiation and a broadening of the concept of climate services.

This study also contributes to the literature on Constructive Technology Assessment. CTA is normally focused on emerging technologies and has never been applied to an emerging knowledge-intensive service market. The basic principles proved also applicable in this context, with some notable differences. Here, new technologies play a smaller role and are less contested than in normal CTA exercises. Besides, the focus is on uncertainties and learning opportunities further down the value chain. The latter makes it possible to link CTA to service development, where it normally feeds into more upstream activities such as policy development and R&D strategies. As in all CTA exercises, the value of the method depends on engaging, realistic and thought-provoking scenarios, broad involvement of stakeholders, and productive discussions among them.

There are several limitations to this study. The exercises were primarily carried out with stakeholders in tourism, urban planning, insurance and development banking. Application of the typology in other sectors will not only lead to new examples, but also to the identification of additional problems, conditions and opportunities that may hinder or stimulate the realization of different kinds of services. It may be worthwhile to investigate contrasting settings – sectors with many small users vs. sector with large users, public vs. private sectors, and sectors with high and low competition – to uncover a variety of dynamics, and to further develop the typology as suitable interactive format for a broad range of settings. Research into the impact of different types of services – for instance focused vs. integrated services – may also uncover which services have the highest added value in which contexts. Also, the use of a CTA approach has limitations. These have partly to do with the method as such, which is aimed at providing anticipatory learning experiences for enactors and selectors, but not at suggesting guidelines to them in the follow-up process. As analyst we have proposed some guidelines for using the typology, but it would be valuable to study empirically how the learning outcomes of the CTA exercises for participants are used in concrete service development processes, also to strengthen the effectiveness of the typology-based interactions. This follow-up would require a case-study or interview approach. Limitations also relate to how CTA was implemented in this project. The workshops had to be carried out in relatively short time-slots, which may have limited the depth of the exchange among stakeholders. Besides, CTA works best when diverse stakeholders collide over contested issues. In this study, the constructive confrontations were limited, because of the relatively likeminded people that wanted to participate in the workshops, and the interview settings in which no real 'contestants' were present. It would be worthwhile to carry out more extensive CTA workshops with a more heterogeneous and adversarial audience, to get a better view of non-use, preferences and challenges.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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